REMARKS

Claims 1 and 7 have been amended. Claims 1 and 6-8 remain pending. Reconsideration and reexamination of the application, as amended, are requested.

The "Background of the Invention" of the present specification addresses some of the various requirements for an electric power steering apparatus. For example, at page 2, line 23 to page 3, line 3, torque ripple or "fluctuations in the steering torque" are discussed, as follows:

> when the fluctuations in the steering torque are larger than those of a road reaction force due to certain factors, it is difficult for a vehicle driver to distinguish the fluctuations of the steering torque from the fluctuations of the road reaction force. Presence of the large fluctuations in the steering torque has a detrimental effect on steering smoothness upon turning the steering wheel to make a slight course change. Addressing this kind of detrimental effect provides improved steerability of the motor vehicle.

Then, at page 3, lines 15 -21, steering ripple or the fluctuations in the steering torque are discussed as emanating from cogging torque, as follows:

> In general, when armature windings are de-energized, cogging occurs between respective magnetic pulls of the stator and respective cores of the armature windings. Cogging is multiplied by a square of a reciprocal of gear reduction ratio of a worm gear mechanism, and the multiplied cogging is then transmitted as fluctuations to the steering wheel through the pinion shaft. The steering torque thus involves fluctuations.

And then, at page 4, lines 19-26, inertia is discussed, as follows:

> ... since an assist torque is produced responsive to a steering torque of the steering wheel, the rotor of the electric motor should have as small inertia as possible. Since, in this event, inertia of the rotor is transmitted to the steering wheel with a force equal to a value proportionate to the square of the reciprocal of the gear reduction ratio of the worm gear mechanism, lowering inertia of the rotor provides a comfortable steering touch or feel.

In view of this, claims 1 and 7 have been amended to require an electric motor having "means for minimizing inertia and for minimizing fluctuations in the steering torque as emanating from a cogging torque". Electric power steering apparatus 10 includes this element as evidenced by the specification at line 13, page 22 to line 22, page 25. The first portion of this passage discusses lowering the inertia by having the rotor light in weight and small in diameter, as seen at line 13, page 22 to line 1, page 23:

In addition, since the electric power steering apparatus 10 provides the steering assist torque in a frequent and suitable manner in dependence on the steering torque exerted by the steering wheel, inertia of the rotor 86 of the electric motor 80 must be reduced to a level as small as possible. Lowering inertia provides for an improved comfortable steering touch. In order to lower inertia of the rotor 86, the rotor 86 may be light in weight and small in diameter.

In review, in order to employ the electric motor 80 in the electric power steering apparatus 10, a first condition must be met to allow the electric power steering apparatus 10 to be small in size to overcome the limited mounting space in the motor vehicle, and a second condition must also be met to allow the rotor 86, having the permanent magnets, to be reduced in outer diameter with a view to lowering inertia while allowing the stator, having the stator windings, to form the outer stator 85.

The next portion of the specification is a transition from the consideration of low inertia which requires the rotor to be light in weight and small in diameter to having the diameter of the rotor large enough to address the necessary number of poles of permanent magnets in order to address the minimization of fluctuations in the steering torque due to clogging, as seen at line 7, page 23 to line 16, page 23, as follows:

> As previously noted above, the outer diameter of the inner rotor 86 is determined by taking the limited mounting space of the electric motor 80 in the electric power steering apparatus 10 and the required low inertia into consideration. If, however, the inner rotor has a smaller diameter than is required, it is difficult to increase the number of poles of the permanent magnets 94a to 94h. In order to provide a comfortable steering touch or feeling of the electric power steering apparatus 10, an allowable range of inertia must be initially considered whereupon the diameter of the inner rotor must be preferably addressed.

Then, the specification discusses the determination of the number of poles of permanent magnets and the number of poles of stator windings in order to reduce clogging. In this regard, there is discussion of Fig. 10 and the effect of the number of poles due to permanent magnets and due to stator windings on smoothness of the steering wheel. See line 17, page 23 to line 17, page 25, as follows:

> With such a consideration, when the diameter of the inner rotor 86 is determined, the permanent magnets 94a to 94h arranged on the periphery of the inner rotor 86 may preferably have eight poles to reduce production cost. Although the number of poles of the permanent magnets 94a to 94h can be increased to more than eight, an increase in the number of the permanent magnets may cause an increase in production cost of the

electric motor 80. In the illustrated preferred embodiment, the inner rotor 86 has been shown by way of example as having the permanent magnets 94a to 94h of eight poles.

In summary, according to the present invention, the diameter of the inner rotor 86 is determined first to allow the inner rotor 86 to have permanent magnets 94a to 94h with eight poles with a view to improving the cogging performance for thereby providing comfortable steering touch, second to allow the electric motor 80 to be small-sized with a view to meeting the limited mounting space of the motor vehicle, and third to allow the inner rotor to have low inertia in a range permitted for obtaining the comfortable steering touch.

With such an inner rotor 86 determined to have permanent magnets 94a to 94h with eight poles, in order to comparatively increase the least common multiple between the number of poles of the permanent magnets 94a to 94h and the number of the stator windings 93a to 93i, the stator is designed to have nine poles of the stator windings 93a to 93i (i.e., nine salient poles 92a to 92i or nine slots). As a result, the least common multiple is 72. Although it is possible for the stator windings 93a to 93i to have more than nine poles, an increase in the number of poles of the stator windings is reflected by an adverse effect on the production cost.

Now, the relationship between the number of poles of the stator windings 93a to 93i of the electric motor 80 and the number of poles of the permanent magnets 94a to 94h, and the smoothness of the steering wheel is described below with reference to the graph of FIG. 10.

When the inner rotor 86 has less than six poles and the number of poles of the stator windings 93a to 93i corresponds to a multiple of three and is less than fifteen, the least common multiple between the number of poles of the permanent magnets 94a to 94h and the number of poles of the stator windings 93a to 93h becomes relatively small.

On the contrary, when the inner rotor 86 has eight poles and the number of poles of the stator windings corresponds to a multiple of three and is less than fifteen, the least common multiple between the number of poles of the permanent magnets 94a to 94h and the number of poles of the stator windings 93a to 93h becomes relatively large. In particular, when the inner rotor has eight poles and the stator windings 93a to 93i have nine poles, the least common multiple becomes 72 and is larger than the other combination. As the least common multiple increases, the cogging effect decreases. As a result, the cogging effect of the electric motor 80 exerted on the steering wheel decreases, thereby providing steering smoothness in the steering wheel 11 as viewed in FIG. 10. For this reason, the electric power steering apparatus 10 is able to cause the steering wheel 11 to provide a comfortable steering touch or feeling to the vehicle driver.

This portion of the specification concludes that in order to minimize inertia and minimize fluctuations in the steering torque as emanating from a clogging torque, that an inner rotor must have eight poles and an outer stator must have nine poles, as seen at page 25, lines 18 - 22.

The above arrangement is a main factor why the electric motor 80 of the electric power steering apparatus 10 is designed to have the outer stator 85 including the nine poles of the stator windings 93a to 93i, and the inner rotor 86 including the eight poles of the permanent magnets 94a to 94h.

The Examiner rejected claims 1 and 6-8 under 35 U.S.C. 103(a) as being obvious on consideration of Konecny in view of Nishiyama et al. These references do not together point to an electric power steering apparatus requiring as a part of the steering assist mechanism an electric motor having means for minimizing inertia and for minimizing fluctuations in the steering torque as emanating from a cogging torque.

Konecny discloses an outer rotor. An outer rotor necessarily has a higher inertia than an inner rotor. The motor of Konecny is not appropriate for an electric power steering apparatus. There is no discussion or motivation provided in the disclosure of Konecny to use the motor it discloses in a power steering apparatus.

Nishiyama discloses an outer stator having twelve teeth with windings thereon. There is no discussion or motivation provided in Nishiyama to use the disclosure of its motor in an electric power steering apparatus, and, particularly, for the purpose of minimizing fluctuations in the steering torque as emanating from a cogging torque.

The Examiner applies Konecny in view of Nishiyama to reject the claims. Neither reference, however, discloses electric power steering apparatus. Konecny in view of Nishiyama do not even point to an electric motor which has the ability to include means for minimizing inertia and for minimizing fluctuations in the steering torque as emanating from a cogging torque when such electric motor is used in an electric power steering apparatus.

As indicated in Figure 10 and the discussion relating to Figure 10 of the present specification, the apparatus of claims 1 and 7 are designed specifically to provide "smoothness of steering handling" for an electric power steering apparatus. There is no disclosure or motivating language in the references to provide the structure as claimed. Claims 1 and 6-8 are non-obvious in view of the cited references and are patentable thereover.

In view of the above, it is submitted that the application is in condition for allowance. Reconsideration and reexamination are requested. Allowance of claims 1 and 6-8 at an early date is solicited.

Respectfully submitted,

MERCHANT & GOULD P.C.
P.O. Box 2903
Minneapolis, Minnesota 55402-0903
(612) 332-5300

Date: 3-16-05

Curtis B. Hamre

Curtis B. Hamre
Reg. No. 29,165
CBH:PLSkaw